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SUMMARY REPORT OF TASK 384-914.(U)

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Summary Report of
Task 384-914
Office of Naval Research
November 1975 - May 1982
H. Uberall, Principal Investigator



Abstract

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A research program on the topic of acoustic scattering from submerged elastic targets, carried out at the Department of Physics, Catholic University, Washington, D.C. under the Principal Investigator Prof. H. Überall is being sponsored by the Office of Naval Research under task NR 384-914. The task is being carried out with the full-time or part-time participation of several research associates and graduate students at Catholic University, and of voluntary collaborators from several Navy laboratories in the Washington area.

The project concentrates on a study of the excitation of resonant vibrations in the elastic targets, on how the effects of the resonances manifest themselves in the acoustic echo, and how these phenomena may be used for target identification purposes. The main achievement of the work so far, we believe, was the isolation of the resonance features in the acoustic scattering process (using a technique first used in nuclear scattering), the establishment of their link to the physical phenomenon of circumferential (surface) waves on the target, and the complete classification of all the individual components that make up the acoustic scattering process on an elastic body, as outlined in the Report "Interior and exterior resonances in acoustic scattering" by G. C. Gaunard, E. Tanglis, and H. Überall, and D. Brill, distributed as Catholic University Technical Report (Interim) September 14, 1981.

Introduction

A research program on the topic of acoustic scattering from submerged elastic targets, carried out at the Department of Physics, Catholic University, Washington, D.C. under the Principal Investigator Prof. H. Überall is being sponsored by the Office of Naval Research under task NR 384-914. The task is being carried out with the full-time or part-time participation of several research associates and graduate students at Catholic University and of voluntary collaborators from several Navy laboratories in the Washington area.

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Highlights

As the highlights of the program activities and achievement, we consider the following:

1) Establishment of the connection between target resonances and surface waves in acoustics in two papers:

H. Überall, L. R. Dragonette, and L. Flax, "Relation between Creeping Waves and Normal Modes of Vibration of a Curved Body", J. Acoust. Soc. Am. 61, 711 (1977).

L. Flax, L. R. Dragonette, and H. Überall, "Theory of elastic resonance excitation by sound scattering", J. Acoust. Soc. Am. 63, 1699 (1978).

2) Invited talk by H. Überall "Modal and Surface Wave Resonances in Acoustic-Wave Scattering from Elastic Objects, and in Elastic-Wave scattering from cavities", given at the IUTAP Symposium Sept. 12-15, 1977 at Northwestern University, and published in the Proceedings of the Conference Modern Problems in Elastic Wave Propagation (J. Miklowitz and J. D. Achenbach, eds.), Wiley 1978.

3) Invited talk by H. Überall "The theory of resonance scattering in acoustics, nondestructive testing, and geophysics" (plus six contributed talks) at a session Resonance Scattering from Objects, 96th Meeting of the Acoustical Society of America, Honolulu, Hawaii, 27th Nov.- 1st. Dec. 1978, J. Acoust. Soc. Amer. 64, S128, 1978.

4) An application of the resonance method to the solution of inverse scattering problems:

G. C. Gaunard and H. Überall, "Deciphering the Scattering Code Contained in the Resonance Echoes from Fluid-Filled Cavities in Solids", SCIENCE 206, 61 (1979).

G. C. Gaunard and H. Überall, "Identification of Cavity Fillers in Elastic Solids using the Resonance Scattering Theory", Ultrasonics 18, 261 (1980).

5) A review paper on the accomplishments of Resonance Scattering Theory up to early 1981:

L. Flax, G. C. Gaunard, and H. Überall, "Theory of Resonance Scattering", Physical Acoustics (W. P. Mason and R. N. Thurston, eds.), Academic Press, N.Y., 1981.

6) Invited talk by H. Überall, "Target information obtained from resonant acoustic echoes" at a session Acoustic Signatures, 103rd Meeting of the Acoustical Society of America, Chicago, Illinois, 26-30, April 1982, J. Acoust. Soc. Am. 71, S61, 1982.

7) A session Elastic Waves, chaired by H. Überall at the 1982 Spring Meeting of the American Physical Society, Washington, D.C., 26-29 April 1982 in which six contributed papers of the ONR-sponsored work were presented.

8) Establishment of the connection between creeping wave theory and the "Singularity Expansion Method" as developed in radar scattering theory:

H. Überall, G. C. Gaunard, and J. D. Murphy, "Acoustic Surface wave pulses and the ringing of resonances", J. Acoust. Soc. Amer. (in press).

9) Establishment of a scheme for characterizing acoustic targets by the spectrum of their mechanical vibrations (which may be excited by acoustic-wave scattering or by other means), patterned after optical spectroscopy and termed by us "Acoustic Spectroscopy":

D. Brill, G. C. Gaunard. and H. "Uberall, "Acoustic Spectroscopy", J. Acoust. Soc. Amer. (in press).

List of Topics

The universality of the realm of Resonance Scattering theory is witnessed by the considerable number of acoustics-related topics to which it has been applied by us, namely:

1) Sound Scattering from Elastic objects:

References No. 1, 2, 3, 4, 5, 7, 8, 11, 14, 16, 18, 24, 28, 37, 39, 40, 41, 42, 43.

2) Elastic-Wave Scattering from Cavities and inclusion

References No. 9, 10, 12, 15, 21, 25, 27, 28,

3) Acoustic Excitation of layer and plate resonances

References No. 13, 22,

4) Sound Scattering from gas bubbles

References No. 15, 17, 19, 32,

5) Inverse Scattering (Determination of target properties via the acoustic echoes)

References No. 20, 23, 29, 34

6) Effective moduli of materials containing multiple inhomogeneties

References No. 32, 33,

7) Acoustic Spectroscopy of Penetrable Objects

References No. 26, 36, 44.

8) Resonances in Geophysics

Reference No. 35

Personnel

The personnel involved in the ONR-supported effort at Catholic University, over the years, consisted of the following:

- 1) Principal Investigator: Professor H. Überall
- 2) Research Associates: Jacob George
Anton Nagl
Keneth A. Sage
G. Mezzorani
P. K. Raju
K. B. Yoo
- 3) Graduate Students
and former*Graduate
Students
G. V. Frisk* (Naval Research Lab.
Washington, D.C.)
J. W. Dickey (Naval Ship Research
and Development Center, Annapolis, MD)
L. R. Dragonette (Naval Research Lab.)
A. J. Haug* (Johns Hopkins Applied
Physics Lab.)
S. G. Solomon (Naval Ship Research
and Development Center, Carderock, MD)
E. D. Breitenbach (Naval Ship Research
& Development Center, Carderock, MD)
Ameenah R. Farhan* (Catholic Univ.)
Don Brill* (Naval Academy, Annapolis, MD)
Eugenia Tanglis (Naval Surface Weapons
Center, White Oak, Silver Spring, MD)
W. R. Hoover (Naval Ship Research &
Development Center, Carderock, MD).

4) Voluntary Collaborators:

H. Huang (Naval Research Lab. Washington, DC)
L. Flax (Naval Research Lab., Washington, DC)
J. D. Murphy (3709 Merlin Way, Annandale, VA 22003)
K. P. Scharnhorst (Naval Surface Weapons Center, Silver Spring)
W. Madigosky (Naval Surface Weapons Center, Silver Spring, MD)
G. C. Gaunard (Naval Surface Weapons Center,
White Oak, Silver Spring, MD)
R. Fiorito (Naval Surface Weapons Center, White Oak,
Silver Spring, MD)

Ph D Theses Completed

J. W. Dickey - 1977
L. R. Dragonette - 1978
E. D. Breitenbach - 1979
S. G. Solomon - 1979

Present Research Associates

Anton Nagl
Kwang-Bok Yoo

Present Graduate Students

Eugenia Tanglis (Naval Surface Weapons Center, White Oak,
Silver Spring, MD)
Goodwin Igiri (Catholic University, Washington, D.C.)
J. V. Subrahmanyam (Catholic University, Washington, DC)
Alexander Vaucher (Catholic University, Washington, DC)
George Zarur (World Resources, Inc.)

Impact of Program

Our theoretical research publications have stimulated a number of experimental studies of surface waves and resonances at several laboratories, notably:

1) Naval Research Laboratory, Washington, D.C. 20375; see, e.g., L. R. Dragonette, "Evaluation of the Relative Importance of Circumferential Waves in Acoustic Scattering from Cylindrical Shells", NRL Report 8216, September 1978, and several other publications.

2) Ecole Normale Supérieure (Université Paris VII, France); see P. J. Welton, M. de Billy, A. Hayman, and G. Quentin, "Backscattering of short ultrasonic pulses by solid elastic cylinders", J. Acoust. Soc. Am. 67, 470 (1980); "Comparison of backscattering of short pulses by solid spheres and cylinders", J. Acoust. Soc. Am. 1982.

3) Université de Haute Normandie, Le Havre, France; see G. Maze, B. Taconet and J. Ripoche, "Influence des ondes de Galérie à Echo sur la difussion d'une onde ultrasonore par un cylindre", Physics Letters 84A, 309 (1981); "Visualization of acoustic scattering by elastic cylinders", J. Acoust. Soc. Am. (submitted); A. Deren et al, "Diffusion d'une onde acoustique par des cylindres: étude expérimentale et théorie des résonances", Acustica, 1982, and about 15 other publications by this group.

The group of Ripoche and Derem has performed very ingenious experiments which measured pure acoustic resonances, and has introduced the concept of "acoustic spectroscopy" independently of us. Experimental work of this type can be expected to lead to practical applications of the resonance theory in due course.

Publications in Refereed Journals

1. Frisk, G. V., Dickey, J. W., and Überall, H., "Surface Wave Modes on Elastic Cylinders", J. Acoust. Soc. Am. 58, 996 (1975).
2. Frisk, G. V. and Überall, H., "Creeping Waves and Lateral Waves in Acoustic Scattering by Large Elastic Cylinders", J. Acoust. Soc. Am. 59, 46 (1976).
3. Dickey, J. V., Frisk, G. V. and Überall, H., "Whispering Gallery Wave Modes on Elastic Cylinders", J. Acoust. Soc. Am. 59, 1339 (1976).
4. Überall, H. and Huang, H., "Acoustical Response of submerged Elastic Structures obtained through Integral Transforms", in Physical Acoustics, Vol. 12, (W.P. Mason and R. N. Thurston, editors), Academic Press, 1976.
5. Überall, H., Dragonette, L. R. and Flax, L. "Relation between Creeping Waves and Normal Modes of Vibration of a Curved Body", J. Acoust. Soc. Am. 61, 711 (1977).
6. Gaunaurd, G. C. and Überall, H. "Acoustics of Finite Beams", J. Acoust. Soc. Am. 63, 55 (1978).
7. Dickey, J. W. and Überall, H. "Surface Wave resonances in sound scattering from elastic cylinders", J. Acoust. Soc. Amer. 63, p. 319, 1978.
8. Flax, L., Dragonette, L. R. and Überall, H. "Theory of elastic resonance excitation by sound scattering", J. Acoust. Soc. Amer. 63, 723, 1978.
9. Haug, A. J., Solomon, S. G., and Überall, H., "Resonance Theory of Elastic Wave Scattering from a Cylindrical Cavity" Journal of Sound and Vibration, Vol. 57, 51, 1978.
10. Gaunaurd, G. C., and Überall, H. "Theory of Resonant Scattering from Spherical Cavities in Elastic and Viscoelastic Media", J. Acoust. Soc. Amer. 63, 1699, 1978.
11. Murphy, J. D., Breitenbach, E. D. and Überall, H., "Resonance Scattering of Acoustic Waves from Cylindrical Shells", J. Acoust. Soc. Amer. 64, 677, 1978.
12. Gaunaurd, G., Scharnhorst, K. P. and Überall, H. "New Method to Determine Shear Absorption using the Viscoelastodynamic resonance-Scattering Formalism", J. Acoust. Soc. Amer. 64, 1211, 1978.
13. Fiorito, R. and Überall, H. "Resonance Theory of Acoustic Reflection and Transmission through a Fluid Layer", J. Acoust. Soc. Amer. 65, 9, 1979.

14. Murphy, J. D., George, J., Nagl, A. and Überall, H., "Isolation of the Resonant Component in Acoustic Scattering from Fluid-Loaded Elastic Spherical Shells", J. Acoust. Soc. Amer. 65, 368, 1979.
15. Gaunaurd, G., Scharnhorst, K. P. and Überall, H. "Giant Monopole Resonances in the Scattering of Waves from Gas-filled Spherical Cavities and Bubbles", J. Acoust. Soc. Amer. 65, 573, 1979.
16. Murphy, J. D., George, J., and Überall, H. "Isolation of the Resonant Component in Acoustic Scattering from Fluid-Loaded Cylindrical Shells", Wave Motion Vol. 1, 141, 1979.
17. Sage, K. A., George J., and Überall, H., "Multipole Resonances in Sound Scattering from Gas Bubbles in a Liquid", J. Acoust. Soc. Amer., 65, 1413, 1979.
18. Dickey, J. W., and Überall, H. "Acoustic High-Frequency Scattering by Elastic Cylinders", J. Acoust. Soc. Amer. 66, 275, 1979.
19. Überall, H., George, J., Farhan, A. R., Mezzorani, G., Nagl, A. Sage, K. A. and Murphy, J. D., "Dynamics of Acoustic Resonance Scattering from Spherical Targets: Application to Gas Bubbles in Fluids", J. Acoust. Soc. Amer. 66, 1161, 1979.
20. Gaunaurd, G. C. and Überall, H., "Deciphering the Scattering Code Contained in the Resonance Echoes from Fluid-Filled Cavities in Solids", SCIENCE 206, 61, 1979.
21. Gaunaurd, G. C., and Überall, H., "Numerical Evaluation of Modal Resonances in the Echoes of Compressional Waves Scattered from Fluid-Filled Spherical Cavities in Solids", J. Appl. Phys. 50, 4642, 1979.
22. Fiorito, R., Madigosky, W. and Überall, H., "Resonance Theory of Acoustic Waves Interacting with an Elastic Plate", J. Acoust. Soc. Am. 66, 1857, 1979.
23. Gaunaurd, G., and Überall, H., "Resonance Method for Identifying Fluids Filling Cavities in Elastic Solids", Transactions of the ASME, 46, 958, 1979.
24. George, J., "Resonances in Sound Scattering from Water Droplets in Air", J. Acoust. Soc. Am. 67, 336, 1980.
25. Brill, D., Gaunaurd, G. C., and Überall, H. "Resonance Theory of Elastic Shear-Wave Scattering from Spherical Fluid Obstacles in Solids", J. Acoust. Soc. Am. 67, 414, 1980.
26. Gaunaurd, G. C., Tanglis, E. and Überall, H. "Surface Wave Interpretation of the Eigenfrequencies of a Finite-Length Fluid Cylinder", J. Acoust. Soc. Am. 67, 764, 1980.

27. Flax, L., and Überall, H. "Resonant Scattering of Elastic Waves from Spherical Solid Inclusions", J. Acoust. Soc. Am. 67, 1432, 1980.
28. Flax, L., Raju, P. K., George, J., and Überall, H., "Resonating Fields Inside Elastic Scattering Objects", J. Acoust. Soc. Am. 68, 973, 1980.
29. Gaunaurd, G. C., and Überall, H., "Identification of Cavity Fillers in Elastic Solids using the Resonance Scattering Theory", Ultrasonics 18, 261, 1980.
30. Flax, L., Gaunaurd, G. C., and Überall, H. "Theory of Resonance Scattering", Physical Acoustics (W. P. Mason and R. N. Thurston, eds.), Academic, NY 1981, Vol. 15, 191-294.
31. Brill, D., Gaunaurd, G. C., Überall, H., "The Response Surface in Elastic Wave Scattering", J. Appl. Phys. 52, 3205-14 (1981).
32. Gaunaurd, G.C. and Überall, H., "Resonance Theory of Bubbly Liquids", J. Acoust. Soc. Am. 69, 362-370, 1981.
33. Gaunaurd, G. C. and Überall, "Resonance Theory of the Effective Properties of Perforated Solids", J. Acoust. Soc. Am. 71, 1982, 282-295.
34. Gaunaurd, G. C., Madigosky, W., Überall, H. and Dragonette, L.R., "Inverse Scattering and the Resonances of Viscoelastic and Electromagnetic Waves", Wave Propagation in Viscoelastic Media (Ed. F. Mainardi), Research Notes in Mathematics, #52, Pitman, 1982.
35. Hoover, W. R., Nagl, A. and Überall, H. "Resonances in Acoustic Bottom Reflection and their Relation to the Ocean Bottom Properties" in Bottom-Interacting Ocean Acoustics, Plenum, New York 1980, p. 209-223.

Papers Accepted

36. D. Brill, G. C. Gaunaurd, and H. Überall, "Acoustic Spectroscopy", J. Acoust. Soc. Am.
37. H. Überall, G. C. Gaunaurd, and J. D. Murphy, "Acoustic Surface Wave pulses and the ringing of resonances", J. Acoust. Soc. Am.
38. A. Nagl, H. Überall, and W. R. Hoover, "Resonances in Acoustic Bottom Reflection and their Relation to the Ocean Bottom Properties", IEEE Transactions of the Geophysics and Remote Sensing Society.

Papers Submitted

39. G. C. Gaunaurd, E. Tanglis, H. Überall, and D. Brill, "Interior and Exterior Resonances in Acoustic Scattering I: Spherical Targets", J. Math. Phys.
40. H. Überall, G. C. Gaunaurd, and E. Tanglis, "Interior and Exterior Resonances in Acoustic Scattering II: Targets of Arbitrary Shape (T-Matrix Approach)", J. Math. Phys.
41. G. C. Gaunaurd and H. Überall, "RST Analysis of Monostatic and Bistatic Acoustic Echoes from an Elastic Sphere", J. Acoust. Soc. Am.
42. S. G. Solomon, H. Überall, and K. B. Yoo, "Mode Conversion and Resonance Scattering of Elastic Waves from a Cylindrical Fluid-Filled Cavity", J. Acoust. Soc. Am.
43. E. D. Breitenbach, H. Überall, and K. B. Yoo, "Resonant Acoustic Scattering from Elastic Cylindrical Shells", J. Acoust. Soc. Am.

44. D. Brill, G. C. Gaunard, and H. Überall, "Mechanical Eigenfrequencies of Axisymmetric Fluid Objects: Acoustic Spectroscopy", Acustica.
45. H. Überall et al, "Electromagnetic and Acoustic Resonance Scattering Theory" (review paper, submitted to J. Wave Motion).

Talks presented by H. Überall since 1977 (Invited talks are underlined).

1. "Regge Pole Character of Resonances in Sound Scattering from Elastic Bodies," 93rd Meeting of the Acoustical Society of America, Pennsylvania State University, June, 1977, (with Dragonette and Flax).
2. "Surface and Through Wave Contributions to Scattering from an Elastic Cylinder" (with Dickey), 9th International Congress on Acoustics, Madrid, Spain, July, 1977.
3. "Breit-Wigner and Surface Wave Resonances in Acoustic-Wave Scattering from Elastic Objects, and in Elastic-Wave Scattering from Cavities," IUTAM Symposium on Modern Problems in Elastic Wave Propagation, Northwestern University, Evanston, Illinois, September, 1977.
4. "General Theory of Spreading and Scattering of Finite Beams" (with Gaunaurd), 94th Meeting of the Acoustical Society of America, Miami Beach, Florida, December, 1977.
5. "New and General Expansion for Differential Cross Sections of Sound Scattered from Impedance Cylinders," (with George), 94th Meeting of the Acoustical Society of America, Miami Beach, Florida, December, 1977.
6. "Resonance Theory for Acoustic Plane Wave Transmission through a Fluid-loaded Layer or Plate," (with Fiorito and Madigosky), 94th Meeting of the Acoustical Society of America, Miami Beach, Florida, December, 1977.
7. "Resonances in Sound Scattering from Elastic Bodies" (with Flax, Dickey, and Dragonette), 9th International Congress on Acoustics, Madrid, Spain, July, 1977.
8. "Resonance Theory of Acoustic Scattering," Indian Institute of Technology, Madras, India, August, 1978 (2 lectures).
9. "Resonance Scattering in Acoustics and in Nuclear Physics," University of Auckland, New Zealand, September 6, 1978.
10. "How Acoustic and Seismic Waves cause Resonances and what we can learn from them," University of Puerto Rico, Mayaguez, Puerto Rico, March 23, 1979.
11. "Resonances in Acoustic Reflections from Elastic Layers," Seminar on Ocean Bottom Effects, University of Miami, Coral Gables, Florida, April, 1979.

12. "Total Elastic Cylinder Cross Section Calculated from Surface and Through Wave Contributions" (with J.W.Dickey), 95th Meeting of the Acoustical Society of America, May, 1978, Providence, R. I.
13. "Multipole Resonances in Sound Scattering from Gas Bubbles in a Liquid" (with K. A. Sage and J. George), 95th Meeting of the Acoustical Society of America, May, 1978, Providence, R. I.
14. "Scattering of Dilational Waves Incident on a Resonating Fluid-Filled Spherical Cavity Inside a Sound-Absorbing Material" (with G. Gaunaurd), 95th Meeting of the Acoustical Society of America, May, 1978, Providence, R. I.
15. "The Theory of Resonance Scattering in Acoustics, Non-destructive Testing and Geophysics" 96th Meeting of the Acoustical Society of America, Honolulu, Hawaii, November-December, 1978.
16. "Dynamics of Acoustic Resonance Scattering from Spherical Targets: Application to Gas Bubbles in Fluids" (with A. R. Farhan, J. George, G. Mezzorani, A. Nagl, and K. A. Sage), 96th Meeting of the Acoustical Society of America, Honolulu, Hawaii, November-December, 1978.
17. "Rayleigh and Lamb Wave Resonances in an Elastic Plate" (with R. Fiorito and W. Madigosky), 96th Meeting of the Acoustical Society of America, Honolulu, Hawaii, November-December, 1978.
18. "Normal Mode Solutions for the Scattering of Elastic Waves from Spherical Solid Inclusions" (with L. Flax), 96th Meeting of the Acoustical Society of America, Honolulu, Hawaii, November-December, 1978.
19. "Viscoelastic Effects in Resonant Sound Scattering from Layered Cylindrical Shells" (with G. C. Gaunaurd), 97th Meeting of the Acoustical Society of America, June 1979, Cambridge, Mass. (H. Überall acting as Session Chairman).
20. "Resonating fields inside elastic scattering objects" (with L. Flax, and J. George), 97th Meeting of the Acoustical Society of America, June 1979, Cambridge, Mass. (H. Überall acting as Session Chairman).
21. "Resonance Theory of Elastic Shear Wave Scattering from Fluid Spheres" (with D. Brill and G. Gaunaurd), 97th Meeting of the Acoustical Society of America, June 1979, Cambridge, Mass. (H. Überall acting as Session Chairman).
22. "Mode Conversion and Resonance scattering of Elastic Waves from a Cylindrical Fluid-Filled Cavity" (with S. G. Solomon), 97th Meeting of the Acoustical Society of America, June 1979, Cambridge, Mass. (H. Überall acting as Session Chairman).

23. "Resonances in Acoustic and Elastic-Wave Scattering"
(with G. C. Gaunaurd), International Symposium on Recent
Development in Classical Wave Scattering, June 25-27, 1979,
Ohio State University, Columbus, Ohio.
24. "Surface Wave Effects in Nuclear and Classical Wave
Scattering Problems", Univ. of Sao Paulo, Brazil,
July 18, 1979.
25. "The Resonances of a finite-length fluid cylinder and
their interpretation in terms of surface waves" (with
G. C. Gaunaurd and E. Tanglis), 98th Meeting of the
Acoustical Society of America, November, 1979, Salt Lake
City, Utah.
26. "Zeroes", "ridges" and poles in the scattering amplitudes
of elastic waves echoing from resonating fluid spheres in
solids and liquids" (with D. Brill and G. Gaunaurd), 98th
Meeting of the Acoustical Society of America, November 1979,
Salt Lake City, Utah.
27. "The Mittag-Leffler expansion and the interpretation of
poles in the scattering amplitudes of waves echoed from
fluid spheres" (with G. Gaunaurd), 98th Meeting of the
Acoustical Society of America, November 1979, Salt Lake
City, Utah.
28. "Identification of Cavity Fillers from their Ultrasonic
Echo", Ultrasonics International 79th Conference, Graz,
Austria, 15-17 May, 1979.
29. "The role of surface waves in scattering processes of
Nuclear Physics and Acoustics, Scattering Theory
Conference, Catholic University, Washington, DC 21-25,
May, 1979.
30. "Elastic Moduli and Effective Moduli of Perforated Visco-
elastic Substances", Euromech Colloquium 127, Taormina,
Italy, April 14-18, 1980.
31. "The Effect of Viscoelasticity on Acoustic Resonances in
a Fluid Layer", *ibid.*
32. "Giant Resonances in Classical and Nuclear Physics",
Physics Department, University of Bologna, Italy, April 21,
1980.
33. T-Matrix analysis of the resonances in sound scattering
from droplets, 99th Meeting of the Acoustical Society of
America, Atlanta, Georgia, 21-25 April, 1980.
34. "Determination of the dynamic shear modulus and loss factor
of rubber", *ibid.*
35. "Acoustic resonances in a viscous fluid layer", *ibid.*

36. "Effective moduli of perforated viscoelastic substances" *ibid.*
37. "R-matrix theory of sound scattering from an absorbing bubble", *ibid.*
38. "R-matrix theory of sound scattering from an absorbing bubble", Spring Meeting of the American Physical Society, Washington, D.C., April 28 - May 1, 1980.
39. "Solution of Inverse Scattering Problems in the Resonance Case", *ibid.*
40. "Resonances in Acoustic Bottom Reflection and their Relations to the Ocean Bottom Properties", Ocean Acoustics Conference, La Spezia, Italy, June 9-13, 1980.
41. "R-Matrix theory of Acoustic Scattering from Fluid Spheres", 10th International Congress in Acoustics, Sydney, Australia, July 9-16, 1980.
42. "Acoustic High-Frequency Scattering by Elastic Cylinders", *ibid.*
43. "Asymptotic Material Characterization via Modal Resonances", 2nd International Symposium on Ultrasonics Materials Characterization, National Bureau of Standards, Washington, DC, June 4-6, 1980.
44. "Resonance Theory of Nuclear, Acoustic, Elastic and Electromagnetic Scattering", Mathematisches Forschungsinstitut Oberwolfach, West Germany, August 3-10, 1980.
45. "Elastic Moduli and Effective Moduli of Perforated Viscoelastic Substances", XV. International Congress on Theoretical and Applied Mechanics, Toronto, Canada, 17-23 August, 1980.
46. "Resonances in Acoustic Bottom Reflection and their Relation to the Ocean Bottom Properties" (with A. Nagl and W. R. Hoover), 100th Meeting of the Acoustical Society of America, Los Angeles, California, Nov. 17-21, 1981.
47. "Resonance Theory of Acoustic Wave Propagation through Bubble Screens" (with G. C. Gaunard), *ibid.*
48. "Resonance Scattering of Ultrasonic Waves" (with G. C. Gaunard), Ultrasonic Diagnostic Center, Thomas Jefferson University Hospital, Philadelphia, PA, March 6, 1981 (Invited).

49. "Rayleigh and Lamb Waves in a Viscous Elastic Plate" (with R. Fiorito and W. Madigosky), 101st Meeting of the Acoustical Society of America, Ottawa, Canada, May 18-22, 1981.
50. "Comparison between our Effective Modulus predictions and those of earlier composite-material theories" (with G. C. Gaunard), *ibid.*
51. "Resonances in Acoustic Bottom Reflection and their Relation to the Ocean Bottom Properties" (with A. Nagl and W. R. Hoover), 1981 International Geoscience and Remote Sensing Symposium, Washington, D. C., June 8-10, 1981.
52. "Interior/Exterior Creeping Waves in the Dynamics of Bubbles Excited by Acoustic Resonance Scattering" (with G. C. Gaunard), International Symposium on Underwater Acoustics, Tel-Aviv, Israel, June 15-18, 1981.
53. "A New Theory for the Transmission and Reflection Coefficient of Layered Systems" (with R. Fiorito and W. Madigosky), *ibid.*
54. "Ultrasonic Resonances and the Effective Properties of Perforated Solids" (with G. C. Gaunard), Ultrasonics International, Brighton, England, June 30-July 2, 1981.
55. "Determination of the Material Parameters of Fluid or Viscoelastic Layers from their Ultrasonic Resonances" (with R. Fiorito and W. Madigosky), *ibid.*
56. "Electromagnetic and Acoustic Resonances Scattering Theory", XXth General Assembly of the International Union of Radio Science, Washington, D.C., August 10-19, 1981.
57. "Resonances and Surface Waves in Nuclear and in Classical Physics," Instituto de Fisica Teorica, Universidad Nacional Autonoma de Mexico, Mexico City, Mexico, August 14, 1981.
58. "Interior and exterior resonances in acoustic scattering by spherical targets" (with G. C. Gaunard, E. Tanglis, and D. Brill), 102nd Meeting of the Acoustical Society of America, Miami Beach, Florida, 30 Nov.-4 Dec. 1981.
59. "Interior and exterior resonances in acoustic scattering by arbitrarily shaped targets" (with G. Gaunard and E. Tanglis), *ibid.*
60. "Uses of monostatic and bistatic echoes from (calibration) spheres for inverse scattering" (with G. Gaunard), *ibid.*
61. "Acoustic spectroscopy" (with D. Brill and G. Gaunard), *ibid.*

62. "Resonance theory of acoustic scattering from objects of arbitrary shape: Finite-cylindrical targets" (with E. Tanglis, and G. C. Gaunaurd). 103rd Meeting of the Acoustical Society of America, Chicago, IL, 26-30 April, 1982.
63. "Sound scattering from elastic objects and their complex eigenfrequencies" (with G. C. Gaunaurd and J. V. Subrahmanyam), *ibid.*
64. "Creeping waves in acoustic scattering and the ringing of resonances" (with G. C. Gaunaurd), *ibid.*
65. "Target information obtained from resonant acoustic-echoes" (with G. C. Gaunaurd), *ibid.*
66. "Mode conversion and resonance scattering of Elastic Waves from a cylindrical fluid-filled cavity" (with S. G. Solomon and K. B. Yoo), Spring Meeting of the American Physical Society, Washington, D.C., 26-29 April, 1982. (Session chaired by H. Überall).
67. "Normal mode acoustic scattering from elastic cylindrical shells" (with E. D. Breitenbach and K. B. Yoo), *ibid.*
68. "Sound scattering from elastic objects and their complex eigenfrequencies" (with J. V. Subrahmanyam and G. C. Gaunaurd), *ibid.*
69. "Creeping-wave transients and the ringing of resonances of acoustic and electromagnetic targets" (with G. C. Gaunaurd, A. Nagl and J. V. Subrahmanyam), *ibid.*
70. "Resonance theory of acoustic scattering from arbitrarily-shaped targets" (with E. Tanglis and G. C. Gaunaurd), *ibid.*
71. "Acoustic spectroscopy" (with D. Brill and G. C. Gaunaurd), *ibid.*

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